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Dr. J. L. E. DREYER, PRESIDENT, in the Chair.

Louis Melville Milne-Thomson, B.A., Lecturer in Mathematics, Royal Naval College, Greenwich, London, S.E. 10,

was balloted for and duly elected a Fellow of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Frederic Douglas Addyman, L.C.C. School of Engineering and Navigation, High Street, Poplar, London, E. 14 (proposed by J. S. Fletcher);

Harold Reynolds Kingston, M.A., Ph.D., Professor of Mathematics and Astronomy at Western University, London, Ontario, Canada (proposed by L. A. H. Warren); and

Arthur Robert Wesley, 9 Devonport Street, Lancaster Gate, London, W. 2 (proposed by F. Robbins).

One hundred and seven presents were announced as having been received since the last Ordinary Meeting, including, amongst others :—

Tychonis Brahe, Opera Omnia, vol. 5, pt. 2 (presented by Dr. Dreyer);

A. S. Eddington, The Mathematical Theory of Relativity;

J. H. Jeans, The Nebular Hypothesis and Modern Cosmogony (Halley Lecture, 1922);

A. A. Mikhailov, Atlas of the Northern Stellar Hemisphere; and

C. S. Wright, Determinations of Gravity; Observations of the Aurora (presented by the Captain Scott Antarctic Fund).

Wave-Lengths of Silicon Lines occurring in the Spectra of B-Type Stars.

By H. Barrell, D.I.C., A.R.C.S., B.Sc.

(*Communicated by Professor A. Fowler, F.R.S.*)

The need for further laboratory observations of the wave-lengths of the lines of silicon which are utilised in the determination of the radial velocities of B-type stars has long been recognised, and has recently been emphasised by Dr. Sebastian Albrecht.* Previous values have not been referred to modern standards of wave-lengths, and in some cases no special effort has been made to produce the lines under conditions giving them suitable definition when adequate dispersion was employed.

An investigation of the various spectra of silicon has been in progress in Professor Fowler's laboratory for some years, but publication of the results has been deferred, pending the more accurate determination of some of the wave-lengths involved. Difficulties in this connection have been caused by the continued detention in Russia of the permanent mounting for the 10-feet concave grating, and by the absence of adequate measures for temperature control with the temporary mounting at present in use. In view of Dr. Albrecht's appeal, however, an attempt has been made to secure the desired re-determinations with every possible precaution to ensure a high degree of accuracy.

The silicon lines which have been used in radial velocity determinations include a pair about λλ 4131, 4128, a triplet with its components near λλ 4575, 4568, 4553, and a pair close to λλ 4116, 4089. They belong respectively to Lockyer's groups II., III., and IV., of silicon lines (designated in this paper by the symbols Si II., Si III., and Si IV.), and require increasing amounts of energy for their production. It is possible, however, to produce all these lines at the same time under appropriate experimental conditions.

For the excitation of the lines in question, condensed discharges were sent through vacuum tubes containing silicon tetrafluoride at pressures low enough to give the lines the requisite sharpness. It was found that much better definition of the silicon lines was obtained when no auxiliary spark-gap was used in series with the tubes. The "end-on" type of discharge tube was employed, and the iron arc in air was the source of reference lines. Lines used as standards of wave-length were selected from Dr. St. John's new list of secondaries and tertiaries, recently published by the International Astronomical Union.† All the silicon lines in question could be photographed on one plate in the first order of the 10-feet concave grating, which gives a dispersion of 5·5 Å per millimetre.

Several of the earlier photographs taken with the grating gave discordant results, the variations amounting to as much as 0·05 Å. Eventually these variations were traced to the following three causes, namely:—

(1) the use of the comparison shutter in front of the plate.

* *Astrophys. Jour.*, 50, 361 (1922); 52, 57 (1923); *Pop. Ast.*, 30, 546 (1922).

† *Trans. Int. Ast. Union*, 1, 41 (1922).

(2) imperfect illumination of the grating by the vacuum tube having its capillary in the "end-on" position.

(3) the "pole effect" in the iron arc at first used as a source of reference lines.

The effect of (1) was easily eliminated by dispensing with the comparison shutter and superimposing the iron arc spectrum on that of the vacuum tube. The lines λλ 4575, 4553 of the silicon triplet are almost coincident with faint iron lines, but the Imperial Ordinary plates used show slightly lower sensitivity in this region as compared with the violet, and it was possible to prevent these faint iron lines being photographed by giving a somewhat shorter exposure. Lines available as standards in the iron spectrum were even then intense enough to be measurable throughout the plate. The measures of the two silicon lines should therefore be unaffected by any blending with iron lines.

In the case of (2), it is doubtful if the "end-on" type of discharge tube, notwithstanding the greater brightness of spectrum which it produces, is suitable for precise work in wave-length determinations, as there is always an excess of brightness along the middle of the emergent beam in the axial direction of the capillary. The difficulty was at least partially overcome by using an achromatic lens of short focal length to focus the emergent beam from the capillary tube on the slit, so that when the slit was opened wide the whole area of the grating appeared to be fully illuminated, so far as could be detected by eye. Experiments with the capillary parallel to the slit were unsatisfactory on account of the long exposures required.

To eliminate "pole effect," a standard iron arc, similar to that recommended by the Wave-lengths Committee of the International Astronomical Union,* consisting of a Pfund arc, operating on 215 volts, with 5 amperes, at a length of 15 millimetres, was used over a central zone 1·5 millimetres in width at right angles to the axis of the arc. An iron rod 6 millimetres in diameter was used as the upper pole, and a bead of iron oxide, placed in a small depression on the top of an iron rod 12 millimetres in diameter, acted as the positive pole. An image of the arc, magnified four times, was projected on the slit by means of an achromatic lens, and the part of the image allowed to fall on the slit was limited to a length of 6 millimetres taken from its central portion. A further refinement was gained by arranging matters so that partly simultaneous exposures could be made on the vacuum tube and iron arc. A thin microscope cover-glass was placed in front of the slit, in the path of the beam from the vacuum tube, and inclined with its plane at an angle of 45° to the beam. The iron arc was placed in such a position that its light was reflected by the cover-glass on to the slit. By reason of the combined effect of the small part of the arc used, the magnified image, and the loss of light at the reflecting surface, the intensity of the light from the arc reaching the slit was greatly reduced. This was a great improvement, since it tended to equalise the exposures for both sources and made it possible to render them effectively simultaneous. Actually, in the case of a tube exposure of one hour's duration, light from the arc was allowed to fall on the slit for one minute every five

* *Trans. Int. Ast. Union*, 1, 41 (1922).

minutes throughout the period. In this way, neither the grating nor the associated apparatus was disturbed during an exposure; creep of lines due to the effect of temperature changes on the grating, or mechanical displacements, if any, could be easily detected by their effects on the definition of the lines.

The results from four plates are given in Table I. The plates have been measured both by Professor Fowler and the author, and the values given are the means of independent and accordant measures. The adopted wave-lengths are the simple arithmetic means of the wave-lengths from the four plates, and are intended to represent the wave-lengths of the silicon lines at nearly zero pressure, as referred to lines of iron in air at atmospheric pressure.

Probable errors of the means have been calculated with the usual formula,

$$r_0 = 0{\cdot}6745 \sqrt{\left[\frac{\Sigma(d^2)}{n(n-1)}\right]}$$

where r_0 is the probable error of the simple arithmetical mean. They are included in Table I.

Two other lines, near λλ 3856, 3863, are also given in the table, as they may possibly be of use in radial velocity determinations. Apart from this, it is interesting to note that these lines are coincident with two previously unidentified lines in the solar spectrum. Wave-lengths are given below for comparison:—

New λ in I. A.	Intensity.	λ in Rowland's System.	Sun.	
			Rowland.	Intensity.
3856·021	8	3856·165	3856·161	1
3862·592	6	3862·736	3862·727	1

Two other lines of Si II. have previously been traced in the solar spectrum by Professor Fowler.*

TABLE I.

Group of Lines.	Plate A.	Plate B.	Plate C.	Plate D.	Adopted Values in I. A.	Probable Errors.
Si II.	3856·017	3856·022	3856·023	3856·024	3856·021	± ·001
	3862·584	3862·595	3862·589	3862·599	3862·592	·002
	4128·050	4128·056	4128·051	4128·054	4128·053	·001
	4130·886	4130·882	4130·882	4130·887	4130·884	·001
Si III.	4552·605	4552·618	4552·611	4552·611	4552·611	·002
	4567·818	4567·826	4567·824	4567·832	4567·824	·002
	4574·731	4574·738	...	4574·740	4574·737	·002
Si IV.	4088·861	4088·863	4088·867	4088·861	4088·863	·001
	4116·098	4116·109	4116·108	4116·101	4116·104	·002

* *M.N.*, 67, 157 (1906).

In Table II. the wave-lengths are corrected to the Rowland scale, which has hitherto been mainly adopted in measurements of radial velocities. It is not considered necessary to include previous laboratory determinations, except those of Hartmann for the λλ 4128, 4131 pair, as these have frequently been collected.* Some values which have been deduced from stellar spectra are given, as they have more often been used as standards in radial velocity determinations. Dr. Albrecht's wave-lengths for the Si III. triplet were computed from the measures of many stellar spectrograms taken at the Lick and Yerkes Observatories, and they are on the average ·013 Å lower than the new laboratory wave-lengths.

TABLE II.

Wave-lengths in Rowland Scale.	Previously adopted Wave-lengths in Rowland Scale.	Source.
3856·165	3856·161	Rowland, in Sun.
3862·737	3862·727	
4128·207	4128·204	Hartmann, *Astrophys. Jour.*, 18, 65 (1903).
4131·038	4131·040	
4552·782	4552·762	Albrecht, in stars, *Publ. Astron. and Astrophys. Soc. of Amer.*, 2, 72 (1915).
4567·995	4567·967	
4574·908	4574·918	
4089·016	4089·12	Frost and Lowater, in 10 Lacertæ, *Astrophys. Jour.*, 40, 268 (1914).
4116·257	4116·33	

The author is greatly indebted to Professor Fowler for the constant assistance and advice received throughout the course of the foregoing measurements.

Imperial College of Science and Technology,
South Kensington, London:
1923 *February.*

* *e.g.* Crookes, *Proc. Roy. Soc.*, 90, A, 512 (1914).

The Spectrum of ζ Tauri. By Dr. William J. S. Lockyer, M.A. (Plate 12.)

Historical.

The earliest reference which can be found in the *Harvard Annals* to the spectrum of ζ Tauri is that given by Miss Annie E. Cannon,* who, in her publication entitled "Classification of 1477 Stars by their Photographic Spectra," describes the spectrum as being of type B3. Previous to this volume the star does not seem to have been photographed at Harvard, as no mention is made of it in vol. xxviii., part i. (1897). This star seems, therefore, to have been photographed there after 1904 May 12.

In 1897 Sir Norman Lockyer † refers to the spectrum in the following terms:—

"This is one of the most extraordinary spectra which has been met with in the Kensington series of photographs. . . . While the lines of hydrogen are fairly sharp and not very broad, many of the lines, especially those of the cleveite gases, are broadened almost into invisibility. . . ."

In 1903 Professors E. B. Frost and W. S. Adams included this star as one of five stars the radial velocities of which vary, and refer to the spectrum as follows ‡:—

"The spectrum of this star is peculiar, as has been noted by Lockyer and probably by others. The conspicuous feature in the region of the spectrum covered by our plates is the remarkable sharpness and intensity of H_γ. . . . Other lines are faintly discernible in the spectrum. . . . These lines are in general so faint and broad, however, that they have commonly not been employed in the determination of the star's motion."

They further say that "the period is probably very long."

In a later publication § (1905), Professor W. S. Adams describes the general features of the spectrum in his communication entitled "The Orbit of the Spectroscopic Binary ζ Tauri," and says his results "showed the period to lie in the vicinity of four and one-half months, and a few trials gave a value of 138 days as most consistent with the observations. . . . No trace of the spectrum of the second component has been found upon any of the plates, the evidence afforded by the remarkably well-defined characters of H_γ being specially conclusive."

In one of the later volumes of the *Henry Draper Catalogue* ‖ (1918), a note on the spectrum of this star reads as follows:—

"On a photograph taken with the 24-inch reflector on a plate stained with pinacyanol the line H_α is distinctly bright. H_β has been found bright at the Lowell Observatory. It is not bright on the Harvard plates. It may be variable."

* *Annals, Harvard Coll. Obs.*, 56, iv. 80. (No date.)
† *Roy. Soc. Proc.*, 62, 53, 1897.
‡ *Astrophysical Journal*, 17, 151, 1903.
§ *Ibid.*, 22, 115, 1905.
‖ 92, 301, 1918.

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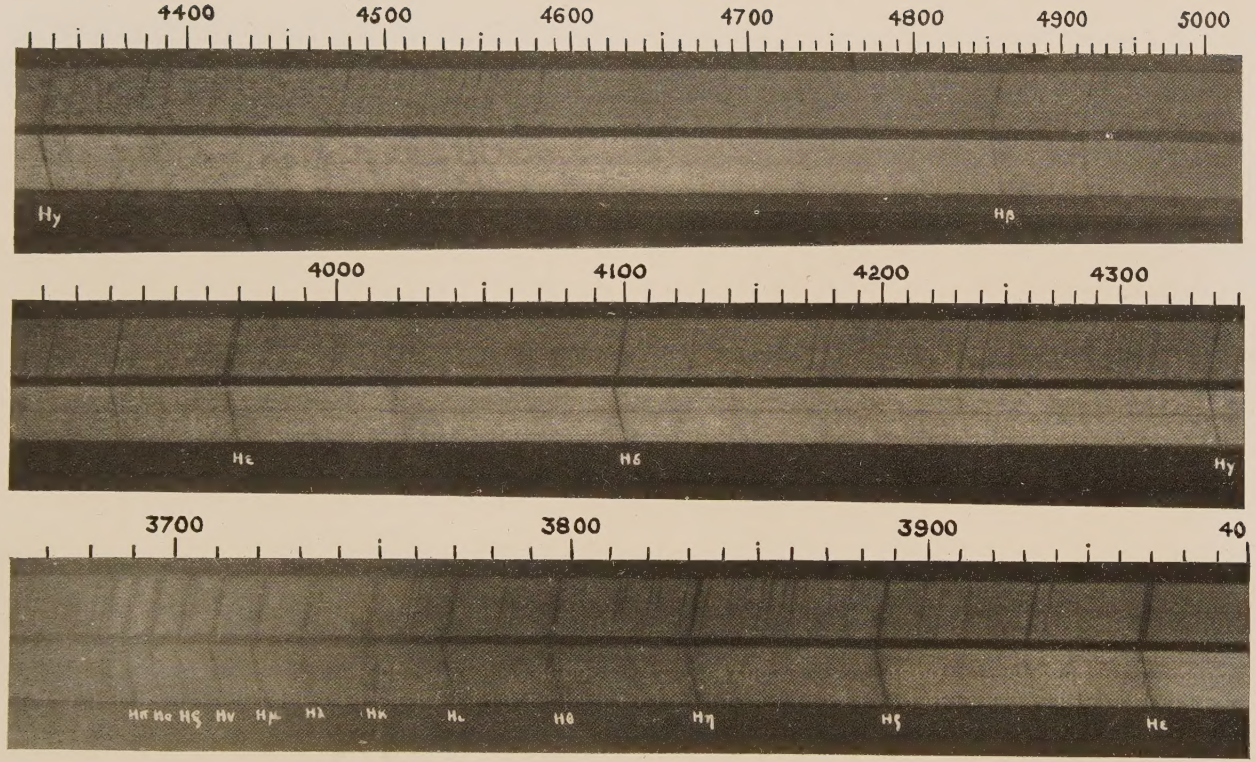

Spectra of (1) α Cygni; (2) ζ Tauri. [Enlarged 4·5 times.]

This is the first instance when any reference has been found to any bright lines in the spectrum of ζ Tauri.

Mr. Paul M. Merrill in 1920 gave a list* of some of the brighter stars of Class B which have bright hydrogen lines, and while specially referring only to the line H_α includes ζ Tauri in the list.

Sidmouth Photographs.

In the ordinary course of photographing stellar spectra with the 9-inch prismatic camera of the Norman Lockyer Observatory, the spectrum of the star ζ Tauri (R.A. $5^h\ 31{\cdot}7^m$, dec. $+21^\circ\ 5'$ [1900], mag. 3, spectrum type B3) was obtained on the night of January 11 of the present year. This star exhibited a very peculiar spectrum.

In the first instance H_β appeared as a very well-defined thin sharp line with *bright components on each side*, while H_γ was very clear with sharp sides but no bright components. Very nearly the same remark which applies to H_γ could be used for the remainder of the hydrogen series, only to a less degree as the violet was approached.

The other lines in the spectrum divided themselves into two main classes, namely, one in which they were exceedingly nebulous or fuzzy, and in some cases very broad, and another in which they were very sharp (see Plate 12).

A reference to the previous history of this star, briefly summarised above, suggested that it would be interesting to repeat this photograph on every fine night for some time to record if possible any changes that might occur. With this intention numerous negatives with various exposures were made, among which the following were the best:—

Neg. No.	Date 1923.	Plate.	Expos. (min.).	Remarks.
250	Jan. 11	Record	17	H_β bright both sides.
258	,, 14	,,	26	,,
262	,, 20	Barnet / Superspeed	23	,,
264	,, 23	Record	40	,,
265	Feb. 4	,,	69	,,
266	,, 4	,,	55	,,
269	,, 21	,,	50	,,

In all these cases while the bright components of H_β are almost equal in intensity, there seems to be a tendency for the violet to be slightly brighter than the red component.

This star was also placed on the working list of the McClean 12-inch prismatic camera to secure photographs every fine night. It was thought that this instrument having a prism of only 12° and a dispersion between H_β and H_δ of 21·4 mm., would more easily produce stronger images of H_β than that of the Kensington 9-inch, which has a prism of 45° and a dispersion of 46·0 mm. between H_β and H_δ.

This, however, was not the case. Out of seven negatives well exposed for H_β and taken on the same kind of plate as that used in the

* *Pub. of the Astr. Soc. of the Pacific*, 32, No. 190, 320, 1920.

Kensington telescope, all exhibited H_β as an exceedingly sharp line, and in only one instance, namely, on February 4 (negative No. 2542), was H_β recorded as accompanied by its bright components.

Considering the ease with which the bright component of H_β was photographed in the spectrum of Nova Cygni (1920·6) when the star was much fainter than magnitude 3·0, this result seemed rather astonishing.

It may now be stated that all the satisfactory photographs secured this year show that H_β has a bright component on each side of it.

In the year 1915 I secured with the McClean prismatic camera an excellent photograph of this spectrum on January 9, using a "Barnet Superspeed Ortho" plate (negative No. 294), and this shows H_β very clearly. In this case there is a very strong bright component on the violet side of H_β, but no trace of any on the red side.

An earlier photograph than any of the above is that contained in the collection of this Observatory, which was taken by Dr. Frank McClean. The negative bears the date 1896 February 4, and was secured with the same 12-inch prismatic camera mentioned above, when it was mounted at Rusthall, Tunbridge Wells.

While the region about H_β is not very dense, the negative shows H_β as quite normal and by no means as a narrow sharp line as it has been recorded here this year. It has a breadth about the same as H_γ, and there are no indications of any bright components.

Thus to summarise the photographs:—

1896 Feb.	H_β.	Dark broad line like H_γ.
1915 Jan.	H_β.	Thin sharp dark line with strong bright component on the violet side.
1923 Jan. } Feb. }	H_β.	Thin sharp dark line. Strong bright components on each side.

The above results show conclusively that H_β is variable, and it will be interesting, therefore, to keep an observation on this star to record the sequence of changes which is undoubtedly occurring.

The General Spectrum.

ζ Tauri formed one of the type stars in Sir Norman Lockyer's stellar classification, and in one of his publications * he included a table showing the wave-lengths of the lines with their chemical origins.

The photographs taken recently at this observatory with the 9-inch prismatic camera are so good, and the dispersion so great, that it was considered important to reduce the best of these and compare the results with those mentioned above to investigate any possible changes in intensities of the lines or even in the lines themselves.

For this purpose two tables of wave-lengths were formed. The first was a reduction of the negative number 265, and the wave-lengths were computed by the Hartmann formula by Mr. D. L. Edwards, covering the spectrum from H_β to H_θ. The second table was made by myself by directly comparing the same negative with a spectrum of α Cygni

* "Catalogue of 470 of the Brighter Stars," *Solar Physics Observatory Publication*, 1902, p. 43.

taken with the same instrument. This table covers practically the whole of the spectrum photographed, namely from λ5018·63 to H_7 (λ3679·35).

The object of making these two distinct tables was necessitated by the fact that many of the nebulous lines became invisible when anything like a high-power magnifier was used. The reduction of the spectrum by comparison with α Cygni was made with an ordinary 3-inch reading-glass magnifying twice and with a watchmaker's eyeglass magnifying four times. The lowest power available for the Hilger micrometer, which was used for the Hartmann formula reduction, was a fourteen-times magnification.

A comparison of the two tables shows that while 86 lines are given for the α Cygni reduction, only 57 are shown by the micrometer measures over the same length of spectrum. The number of lines given in the South Kensington table for the same region amount to 76. The total number of lines measured in each reduction are as follows:—South Kensington, 76; reduction by formula, 58; α Cygni comparison, 104.

Instead of reproducing the three tables mentioned above, only that made by the comparison with α Cygni is given. In this table the intensities, which are only approximate, are indicated by I (max. 10) and the appearance of the lines by A. The abbreviations under A are as follows:—

d. diffuse. *s.* sharp. *f.* faint.
b. broad. *m.s.* moderately sharp. *v.* very.

TABLE I.

Wave-lengths of ζ Tauri.

			Chemical Origin.					Chemical Origin.	
λ.	I.	A.	λ.	O.	λ.	I.	A.	λ.	O.
3679·3	..	ms	3679·35	H_7	3833	2	d	3833·5	He
3682·8	..	ms	3682·81	H_σ	3835·4	8	ms	3835·4	H_η
3686·8	..	ms	3686·83	H_ρ	3838·4	1	ms	..	..
3691·5	..	ms	3691·55	H_π	3845·5	1	f	..	..
3697·1	..	ms	3697·15	H_o	3849·7	1	f	3849·70	Ni+
3703·8	..	ms	3703·85	H_ξ	3853·8	1	f	3854·2	Si II+
3711·8	..	ms	3711·8	H_ν	3856·2	2	s	3856·2	Si II+
3721·9	..	ms	3721·9	H_μ	3862·7	2	s	3862·7	Si II+
3727	..	ms	..	..	3872·4	1	f	3871·80	He
3734·3	..	ms	3734·3	H_λ	3878·7	1	f	3878·9	V +
3737 ?	..	s	3736·9	Ca+?	3889·0	10	ms	3889·0	H_ζ
3741 ?	..	s	..	..	3900·7	2	s	3900·7	Ti+
3750·1	..	ms	3750·1	H_χ	3905·7	3	s	3905·66	Cr+
3770·6	..	ms	3770·6	H_ι	3926	..	d	3926·5	He
3797·9	8	ms	3797·9	H_θ	3933·8	4	vs	3933·8	Ca+
3801 ?	1	fs	..	..	3936·0	1	s	3935·9	Fe+
3807	1	fs	3805·75	He	3938·6	1	fs	..	..
3819·7	..	bd	3819·7	He	3947	3	s	3947·5	O ?

TABLE I.—*continued.*

λ.	I.	A.	Chemical Origin. λ.	Chemical Origin. O.
3961·6	1	s	3961·6	O ?
3964	2	d	3964·7	He
3968·6	1	f	3968·6	Ca+
3970·1	10	s	3970·1	He
3995	2	d	3995·2	N
4002·7	1	s	4002·7	Fe+
4005	1	ms	..	..
4009	..	d	4009·3	He
4024·6 4028·5	..	d vb	4026·3	He
4048·9	1	fs	4048·9	Fe+
4053·9	1	fs	4053·8 4053·9	V+ Ti+
4067·2	1	fs	4067·3	Ni+
4077·9	1	fs	4077·88	Sr+
4101·7	10	s	4101·7	H_δ
4111·2	1	f	4111·25	Cr+
4120	..	d	4120·9	He
4128·1 4131·1	..	vd	4128·1 4131·1	Si II+ Si II+
4143	..	vd	4143·7	He
4173	2	ms	4173·5 4173·7	Fe+ Ti+
4179·0	2	s	4178·95	Fe+
4233·2	3	s	4233·25	Fe+
4242·6	..	d	4242·54	Cr+
4290·4	1	ms f	4290·38	Ti+
4294·2	1	ms f	4294·20	Ti+
4296·7	1	ms f	4296·65	Fe+
4303·3	1	ms f	4303·34	Fe+
4308·1	1	ms f	4308·10	Ti+
4315·1	1	ms f	4315·14	Ti+
4321·2	1	ms f	4321·20	Ti+
4326	1	ms f	4325·9	O ?
4336	..	f	..	..
4340·5	10	s	4340·5	H_γ
4344	2	ms	4344·19 4344·45	Mn+ Ti+
4352	4	vs	4351·93	Fe+
4357·7	3	s	..	..
4367·8	1	d	4367·84	Ti+
4375	1	s	4374·90	Ti+
4385·5	3	vd	4385·55	Fe+
4388	..	vd	4387·93	He
4417·8	2	d	4417·88	Ti+
4471·7	5	vd b	4471·7	He
4481·3	3	vd	4481·30	Mg+
4489	..	d	4488·49 4489·35	Ti+ Fe+
4491·6	1	ms	4491·57	Fe+
4501·5	1	ms	4501·45	Ti+
4508·5	1–2	ms	4508·46	Fe+
4515·5	3	ms	4515·51	Fe+
4520·4	1–2	ms	4520·40	Fe+
4523·6	1–2	ms	4522·69	Fe+
4534·1	1	ms	4534·14	Ti+
4541·4	1	ms	4541·40	Fe+
4549·8	5	ms	4549·64 4549·81	Fe+ Ti+
4556·1	2	ms	4556·10	Fe+
4563·9	1	ms	4563·94	Ti+
4576·5	1	ms	4576·51	Fe+
4584·0	4	s	4584·02	Fe+
4588·4	2	d	4588·38	Cr+
4619·0	2	ms	4618·97	Cr+
4629·5	2	ms	4629·50	Fe+
4713·3	..	d	4713·36	He
4824·3	1	ms	4824·33	Cr+
4836·2	1	ms	4836·40	Cr+
4848·5	1	ms	4848·44	Cr+
4861·51	10	s	4861·49	H_β
4921·9	..	d b	4921·93	He
4924·1	..	d b	4924·11	Fe+
5015·6	..	ms	5015·67	He
5018·6	..	ms	5018·63	Fe+

The main features, gathered from the comparison of the three tables, were as follows:—

(1) All the broad and diffuse lines are due to helium, in which the double-diffuse and double-sharp series, and also the single-principal and single-diffuse series are represented. Excluding the hydrogen lines, 15 per cent. of all lines are due to helium.

(2) The sharp and, on the whole, fainter lines are in the main due to the following ionised metals (the percentages of lines, with the exclusion of hydrogen):—

Calcium, 3 per cent.; magnesium, 2 per cent.; titanium, 26 per cent.; iron, 25 per cent.; chromium, 11 per cent.; silicon, 5 per cent.; nickel, 3 per cent.

(3) There are no lines of intensity 2 or greater in the South Kensington reduction which have not their equivalents in the new measures.

(4) All lines of intensity 1 or greater in the Hartmann reduction are represented in the α Cygni reduction with the exception of seven lines of intensity 1, of which only one appears in the South Kensington List.

The line λ4858·2 in the Hartmann reduction was measured as a dark line, but in the α Cygni reduction it was considered as an effect of contrast against the bright component of the H_β line.

(5) There is only one line of intensity greater than 1, namely λ4357·7 intensity 3, that has not been assigned a probable chemical origin, and finally

(6) There is no ground for considering that the new spectra differ at all from that taken at South Kensington (with the exception, of course, of the line H_β), when due regard is made to the difficulties of measurement of the lines and possibly the different qualities of the photographs employed.

Absolute Magnitude and Parallax.

In a recent communication to the Society * Mr. D. L. Edwards gave the results of an investigation on the parallaxes of B-type stars. It was considered of interest, therefore, to apply these results to the B-type spectrum of ζ Tauri, and with this intention he has measured six of the best negatives. In all cases the helium lines were used, and while λ4472 and λ4388 were compared with the H_γ line, λ4144 was measured against the H_δ line. The measures were difficult in consequence of the nebulous and broad nature of the helium lines, but the absolute magnitudes derived were fairly consistent as the following results show:—λ4472, abs. mag. −2·0; λ4388, abs. mag. −2·3; λ4144, abs. mag. −1·9.

The mean of these values is −2·1, giving a parallax of 0″·009.

Comparing this value with the hypothetical parallaxes published by Plummer,† 0″·011, and Kapteyn,‡ 0″·010, the agreement may be considered fairly satisfactory.

* *Monthly Notices R.A.S.*, 83, No. 1, 47, 1922.
† *Ibid.*, 73, 177.
‡ *Astrophysical Journal*, 47, 278.

Note on the Absorption of Radiation inside a Star.

By F. A. Lindemann, F.R.S.

In a most interesting paper in the November number of the *Monthly Notices of the Royal Astronomical Society* Professor Eddington examined the absorption of radiation by stellar material. His main conclusion was that an electron which encounters an ionised atom will be captured if, and only if, it actually hits the nucleus of the atom. This conclusion is so startling that it is perhaps worth while to see whether there is no alternative way of looking at the question.

It will probably be agreed that the common view of a dynamical equilibrium such as a gas largely ionised by temperature is to consider that the ion lacks almost all the time those electrons whose ionisation potential corresponds to an energy materially less than the energy of thermal agitation; that the electrons whose energy of dissociation is of the same order as that of the electrons colliding with them are constantly being set free and replaced; finally, that the electrons which are so firmly bound that their ionisation potential corresponds to a much greater energy than that of thermal agitation are attached almost permanently to the nucleus. The energy of thermal agitation at the temperature assumed by Professor Eddington, namely, 5640000°, corresponds to a potential drop of 714 volts. Hence one would expect the electrons whose ionisation potential is much less than 714 volts to be missing almost always, those whose ionisation potential is of the order of 714 volts to be constantly removed and replaced, and the K and L electrons to be almost permanently attached to the nuclei. It is well known that an electron having a velocity greater than the ionisation potential on colliding with an atom may, and often does, ionise the atom, losing in the process the energy necessary to remove the other electron from the atom. Not every collision is effective, but in 100-volt electrons in air about one collision in three produces an ion, and even the very fast β rays produce one ion every three hundred collisions. It seems natural to suppose, therefore, that the electrons inside a star have similar properties. In this case electrons colliding with ions containing electrons whose energy of dissociation is less than their own will liberate these electrons and themselves be captured if they have lost too much energy to the newly liberated electron. What proportion of the collisions will result in this process of replacement it is of course difficult to say, but it seems likely that it will be of the same order as the fractions quoted above.

Professor Eddington's paper appears to envisage a very different mechanism. Here electrons are only liberated from the ions photo-electrically, the number so liberated in unit time being given by the absorption coefficient. The number calculated in this way is comparatively small, some 10,000 times less than the number of encounters with an atom per second,* and Professor Eddington assumes, therefore, that only one encounter in 10,000 can result in recombination. It may be

* This number is somewhat indefinite, since the number of encounters per second with the ions depends upon their radius, which is uncertain. The exact figure used, however, in no way affects the argument.

shown, assuming ordinary mechanics, that approximately one electron in 10,000 would hit the nucleus, and Professor Eddington concludes therefrom that this is the condition for recombination.

Physically it seems almost inconceivable that this should be true. Taking iron, for instance, as Professor Eddington does, the energy of an electron when it struck the nucleus at a distance of $8{\cdot}7 \cdot 10^{-13}$ from the centre would be $6{\cdot}8 \cdot 10^{-6}$ ergs.

Presumably the electron would possess initially an energy corresponding to the temperature and retain an energy proper to the orbit it finally selected, and the difference between these two energies, something between 10^{-10} and 10^{-9} ergs, would be radiated. It seems unlikely that an electron should gather the enormous energy of $6{\cdot}8 \cdot 10^{-6}$ ergs, collide with the nucleus, lose about 0·01 per cent. of its energy, and then fall back into its appropriate orbit. Yet this seems to be the only way of interpreting Professor Eddington's suggestion that the electron, having discharged its surplus energy in an inelastic impact, drops tamely into a vacant place in one of the satellite rings. Further, it would be strange if an electron could pass and repass the K and L electrons in this way without disturbing them. The normal view would probably be that an electron only penetrates to an energy level equal to its own energy. Again, atoms with vacant places in their electron systems such as oxygen and chlorine notoriously absorb electrons readily. How much more easily would one expect them to be captured by ions. Yet on Professor Eddington's theory they could traverse some 10,000 ions unchecked.

For all these reasons Professor Eddington's conclusion seems so unlikely, that it appears doubtful whether the last step in his argument is justified. What he has shown is that one collision in 10,000 results in the recombination of an electron without the production of a new one by collision. This fraction happens to be of the same order as the proportion of electrons which would strike the nucleus if the classical mechanics held. But the fact that these figures happen to agree in no way proves that hitting the nucleus is a necessary condition for recombination. The ratio of the area included in one of the stable orbits to the area swept by an electron is of the same order, but this does not justify the conclusion that an electron must actually cut a stable orbit in order to be captured. Or again, for instance in iron, where there are some thirteen bound electrons, the chance of their all being on one side of the nucleus at any given moment is of the same order, but nobody would conclude that this condition decided whether an electron was captured or not. Unless better evidence than the numerical coincidence can be adduced, it would therefore seem dangerous to conclude that an electron is only captured if it hits the nucleus. As set out above, the conception is so alien to all one's ordinary conceptions, and apparently, as far as ionisation by collision is concerned, so much at variance with established experimental facts, that it would seem probable that it will have to be abandoned.

Clarendon Laboratory, Oxford:
1923 *March* 7.

*Proper Motions of the Stars in the Neighbourhood of M*36 (*N.G.C.* 1960).

By Cecilia H. Payne.

(*Communicated by Professor A. S. Eddington, F.R.S.*)

1. The measurements here recorded were carried out upon four plates taken on the Sheepshanks Equatorial of Cambridge University Observatory. The particulars of the plates are as follows:—

Plate No.	Date.	Exposure.
138A	1903 Jan. 15	30^m
S11	1908 Feb. 3	1^h
1100	1921 Feb. 3	$1\frac{1}{2}^h$
1359	1923 Jan. 16	2^h

Plates 138A and S11 were taken direct in the usual manner. Plates 1100 and 1359 were exposed film outwards, the plate thus being taken through glass. Each plate showed one image of each star. Plates 138A and 1100 were placed film to film, and the distances between corresponding images were measured in the Cambridge measuring machine. Plates S11 and 1359 were then similarly treated.

2. The methods of measurement and reduction were those described by W. M. Smart (*Monthly Notices*, 1921 June). The plate-constants were determined with the aid of 32 selected stars, both the method of Christie and Dyson, and the method of least squares being used. The selected stars are marked with an asterisk in the table.

3. Table I. gives a summary of the results.

Column 1, headed "Potsdam No.," gives the number assigned to the star in the Potsdam Catalogue. I. and II. refer to the Potsdam plates 358 and 517 respectively. The field was plotted from the values of x and y determined for the plate, and also from the R.A. and Dec. given by the Potsdam Catalogue. The stars were then individually identified.

The next three columns, headed *No., x, y, give the number assigned to the star when tabulating the images on the Cambridge plates, and its x and y co-ordinates on the plate, respectively.

The next three columns, headed Mag., μ_x, μ_y, give the magnitude, and the absolute centennial proper motions in x and y respectively. The derivation of magnitudes and absolute proper motions from the measurement of the plates is described below.

TABLE I.

	Potsdam No.	*No.	x.	y.	Mag.	μ_x.	μ_y.		Potsdam No.	*No.	x.	y.	Mag.	μ_x.	μ_y.
						″	″							″	″
	..	*63	30·9	12·9	10·0	+0·6	−2·7		II. 292	53	28·3	12·4	9·9	−0·2	+0·5
C	..	129	30·3	20·2	9·1	+0·9	−0·1	C	II. 294	103	28·3	17·0	9·8	+0·6	−0·2
	II. 273	*208	30·1	24·4	9·9	+2·9	−0·3		II. 297	207	28·1	24·2	9·8	+1·4	+1·2
	II. 275	46	30·0	11·0	6·1	−0·8	+2·4	C	II. 300	*102	28·0	18·4	10·1	+0·5	−0·7
	..	18	30·0	7·7	9·8	−0·3	−1·8		II. 302	72	27·9	14·2	9·3	−1·2	−0·5
	..	9	28·4	7·2	9·2	−0·4	−1·3		..	*250	27·7	26·7	9·1	+1·6	−1·5

TABLE I.—*continued.*

	Potsdam No.	*No.	x.	y.	Mag.	μ_x.	μ_y.
						″	″
C	II. 309	141	27·5	21·5	9·0	+0·4	−0·2
	II. 311	*62	27·4	13·0	7·9	−1·2	−3·6
	II. 319	*83	26·9	16·3	9·7	+1·4	+0·4
	I. 1	76	26·4	15·5	11·0	+1·3	−1·0
	..	6	26·2	6·2	9·3	+4·0	+0·6
	I. 5	167	26·1	22·2	9·9	+1·5	−0·7
	I. 7	82	25·6	16·6	9·8	+0·9	−0·2
	..	126	25·3	20·3	10·6	−0·8	−0·1
	I. 8	257	25·1	28·0	10·0	+2·3	−0·5
	I. 9	166	25·0	21·9	9·9	+2·2	−1·0
	I. 10	140	25·0	21·5	10·6	+1·6	+0·2
	..	5	24·9	5·8	9·8	+2·6	+2·7
	I. 11	139	24·8	20·9	11·0	−0·9	+0·2
	I. 13	*71	24·5	14·4	9·8	+1·9	−2·0
	I. 14	125	24·5	20·1	9·3	0·0	−1·3
C	I. 15	*60	24·5	12·6	8·7	+0·5	−0·8
	I. 16	255	24·3	28·2	9·4	−1·3	−0·6
	I. 17	*256	24·3	28·4	10·1	+0·3	−1·5
C	I. 18	164	24·3	27·0	10·8	+1·4	−1·3
	I. 19	292	24·0	33·9	10·3	+4·2	−4·3
	..	*70	23·3	13·5	10·3	+0·2	−2·3
	..	*220	23·2	25·0	9·9	−1·7	−0·4
	I. 24	101	23·1	18·2	10·0	+1·5	−0·4
	I. 26	249	22·8	26·7	8·0	−1·5	−1·5
C	I. 29	*81	22·7	16·3	9·6	+0·5	−1·2
	I. 30	*290	22·5	34·0	9·9	+2·5	−0·3
	I. 31	*248	22·6	27·1	10·5	+1·1	−4·0
	I. 32	*278	22·2	32·4	10·3	+1·7	−0·1
	I. 33	*291	22·5	24·7	8·6	+0·3	+1·8
	I. 38	116	22·2	18·8	10·5	+2·2	+0·8
	I. 39	*238	21·9	26·5	10·3	−0·5	−0·6
	..	247	21·8	27·3	9·2	+0·2	+0·1
	I. 44	162	21·7	22·4	10·3	−1·1	−1·0
	I. 45	100	21·5	18·4	9·3	+1·0	
	..	36	21·2	10·2	10·5	+0·9	+2·9
	I. 47	236	20·7	26·0	8·5	−1·2	−0·8
C	I. 48	161	21·0	22·2	9·9	+0·5	−1·8
	..	35	20·8	9·8	11·0	+4·4	−0·8
C	I. 50	191	20·7	23·3	10·1	+0·9	−0·7
	I. 51	237	20·6	25·8	10·5	+0·1	+0·2
C	I. 52	218	20·6	24·8	9·7	+1·0	−0·9
C	I. 55	160	20·2	22·2	10·2	+0·4	−1·2
C	..	74	20·2	15·5	8·8	+0·5	−0·8
	..	59	20·2	13·0	10·5	−0·9	+5·1

	Potsdam No.	*No.	x.	y.	Mag.	μ_x.	μ_y.
						″	″
C	I. 56	217	20·1	25·0	10·6	+0·9	−0·4
C	I. 59	159	19·8	22·2	9·4	+0·5	−1·7
C	..	189	19·6	22·6	10·1	+0·5	−1·3
C	I. 60	206	19·4	24·6	9·7	+0·2	−0·7
C	I. 62	121	19·6	20·2	9·9	+0·1	−1·0
	I. 64	205	19·5	24·2	10·5	+1·3	−2·4
C	I. 65	190	19·5	23·5	9·8	+0·4	−0·8
C	I. 66	204	19·5	23·8	10·3	+0·6	−1·0
C	..	158	19·4	22·4	10·0	+1·1	−1·6
	I. 70	94	19·4	16·8	11·0	+0·2	−1·4
	I. 74	157	19·3	21·7	9·8	−0·6	−1·0
	I. 78	136	19·1	20·2	10·1	+2·0	−0·3
C	I. 79	235	19·2	25·8	10·0	+0·7	−0·9
C	..	188	19·1	23·1	9·5	+0·7	−1·9
C	..	186	19·1	22·8	8·8	+1·0	−1·7
C	..	187	19·1	22·6	10·5	+0·3	0·0
C	I. 80	120	19·1	20·0	8·6	+0·9	−1·2
C	I. 81	156	19·0	21·8	9·4	+0·6	−1·2
C	I. 82	245	19·0	27·4	10·0	+0·2	−0·7
C	..	184	19·0	23·4	..	+1·0	−1·7
	I. 86	24	18·9	9·0	10·7	+2·6	+0·8
C	..	*261	18·8	29·2	9·5	+0·2	−0·2
	..	183	18·8	23·4	10·2	+0·7	+1·0
C	I. 88	119	18·7	20·2	10·4	+0·4	−0·1
C	..	182	18·6	23·4	9·8	+1·7	−1·0
C	I. 91	135	18·6	20·9	10·3	+0·9	−0·8
	..	181	18·5	23·4	9·9	+0·3	+0·4
C	..	180	18·5	22·8	8·7	+0·2	−0·4
	..	203	18·4	24·1	10·6	−0·4	−0·2
	I. 98	134	18·3	·6	10·9	+0·1	−0·121
	I. 99	133	18·2	21·5	10·3	+0·7	−2·2
	I. 112	8	18·3	6·9	9·7	+0·7	
	I. 113	152	18·2	22·2	8·3	+0·9	−2·2
	I. 114	45	18·4	11·1	8·9	+2·4	−0·7
	..	179	18·2	23·5	11·0	+2·9	−0·8
C	..	155	18·2	22·5	9·6	+0·6	−1·8
	..	154	18·2	22·4	11·0	+1·5	+1·2
C	..	153	18·2	22·3	9·0	+0·3	−1·5
C	..	178	18·1	23·4	10·0	+0·2	0·0
C	..	176	18·0	23·0	8·7	+0·2	−1·1
C	..	175	17·9	22·9	8·6	−0·1	−0·4
C	..	200	17·8	23·8	9·0	+1·3	−0·9
	..	174	17·6	23·3	10·6	0·0	−2·2
	..	173	17·6	23·2	10·5	+0·2	−0·7

TABLE I.—*continued.*

	Potsdam No.	*No.	*x.*	*y.*	Mag.	μ_x.	μ_y.
						″	″
	..	172	17·6	22·9	8·5	+2·8	−0·3
	..	49	17·6	12·4	10·3	−1·1	0·0
C	I. 123	199	17·5	24·3	10·8	+0·8	−0·4
	..	93	17·5	17·1	9·8	+1·7	+0·1
C	I. 126	154	17·4	22·1	8·2	+0·8	−0·9
	I. 127	98	17·4	18·1	11·0	+3·5	−2·0
C	I. 128	234	18·0	25·8	9·9	+0·7	−0·5
	..	3	17·4	6·1	10·1		
	I. 129	171	17·3	23·3	10·7	+0·4	+0·4
	..	254	17·1	28·2	11·0	−3·5	−5·4
C	..	198	17·1	24·4	9·7	+1·4	−0·1
	I. 138	196	16·8	24·6	11·0	+0·4	−2·3
	I. 139	195	16·8	24·5	8·6	+0·5	−1·7
C	I. 140	150	17·1	22·2	10·7	+1·4	−0·3
	I. 141	149	16·6	21·8	8·5	+1·9	−1·6
	..	197	17·0	24·3	11·0	+2·5	−2·0
	..	170	16·1	23·0	9·3	+0·4	+0·6
	..	*244	16·0	27·4	9·1	+0·1	−0·8
	I. 149	194	15·8	24·2	10·6	+1·0	−8·5
	I. 150	33	16·0	10·2	9·7	+0·1	
	I. 151	193	15·7	23·8	9·5	+1·1	−2·4
	..	113	15·6	19·4	10·7	+1·2	+0·4
	..	*260	15·5	29·1	10·2	+0·7	0·0
	I. 156	*92	15·5	17·1	10·7	+2·4	−0·6
	I. 158	58	15·4	12·9	10·2	0·0	−1·1
C	I. 159	*91	15·1	16·6	10·4	+0·9	−0·6
	I. 160	23	15·2	9·0	7·6	+1·7	+0·6
	I. 162	*57	15·0	13·2	10·7	+1·4	−1·1
	I. 164	90	14·8	17·4	9·4	+2·7	−0·3
	I. 165	22	15·0	9·0	9·5	+0·1	−1·2
	I. 166	69	14·9	14·5	8·9	+0·2	−6·6
	I. 168	192	14·7	23·8	9·6	+0·8	−1·1
	I. 169	132	15·3	21·0	9·5	+0·4	−2·4
	I. 174	*276	13·6	32·5	9·4	+1·4	−0·3
	I. 177	277	14·1	32·6	9·5	−0·6	−1·9
	I. 184	97	13·5	18·4	10·2	+0·9	−0·6
	..	*42	13·4	11·4	10·4	+0·8	−0·3
	I. 202	243	11·8	27·5	9·2	+0·6	−2·5
	I. 210	*210	12·4	25·4	9·6	+1·0	−1·1
	..	169	12·0	23·5	9·8	+4·7	−2·2
	..	111	11·9	19·1	9·7	+0·5	−0·4
	..	*67	11·9	4·4	10·5	+1·6	−1·1
	I. 213	293	11·8	34·8	7·6	+1·6	
	..	66	11·5	14·0	9·6	+1·8	
	..	110	11·4	18·8	10·3	−0·3	−2·5
	I. 217	12	10·7	8·0	10·0	−1·0	+1·4
	..	2	10·7	6·0	9·6	+0·5	+1·2
	I. 220	*87	10·2	17·0	10·1	+0·2	−1·1
	I. 221	86	10·0	17·0	10·2	+0·8	−0·1
	..	*65	9·8	13·6	9·6	+0·1	−1·2
	I. 230	40	9·8	10·7	8·4	+2·9	−1·7
	..	1	9·6	5·8	9·6	−6·5	−1·9
	I. 233	147	9·4	22·0	8·1	+0·9	−3·0
	I. 242	251	9·1	27·8	9·7	+0·5	+1·0
	I. 244	*242	9·0	27·2	9·4	−0·2	−0·1
	I. 253	145	8·6	22·3	10·6	+0·9	−3·7
	..	286	8·1	34·3	9·7	+2·7	−0·1
	..	55	7·9	13·0	9·7	+0·1	−3·4
	I. 267	108	7·6	19·5	9·2	−0·1	−0·7
	..	*64	7·5	14·2	10·2	+0·6	+0·1
	I. 273	95	7·3	18·0	10·0	+1·5	+0·5
	..	*266	7·1	29·9	9·6	−0·6	+0·1
	..	281	6·6	33·1	9·0	+0·3	−7·0
	I. 272	269	6·2	31·4	9·8	+0·9	+0·1
	I. 281	226	5·9	26·0	10·1	+1·7	−0·4
	I. 287	105	6·6	19·5	10·1	+0·2	−0·2
	I. 288	130	6·6	21·4	9·6	+0·6	−0·3
	..	54	5·2	13·0	8·8	+5·9	−2·1
	..	285	5·0	34·0	8·4	+2·0	−4·1
	..	259	5·0	28·9	8·7	+1·0	−1·9

4. *Derivation of the Magnitudes.*—The diameters of all the direct images were measured for each pair of plates. A curve was then formed by plotting the measured diameter against the photographic magnitude given in the Potsdam Catalogue, a separate curve being constructed for each plate. When the best curve had been fitted to all the points, the magnitudes of the stars were determined by interpolation from it, and the arithmetic mean of the values from the two plates was adopted.

5. *Derivation of the Absolute Proper Motions.*—The measured motions from the two plates were weighted equally.

The field does not contain a star which occurs in Boss' Catalogue or the Cincinnati Catalogue. The correction to be applied for reduction to absolute proper motion must be determined indirectly. For this purpose we use Kapteyn's formula * for the mean parallax of a star of given magnitude

$$\pi_m = 0''.016\,[0.75^{m-5.5}]$$

Using this formula we obtain the mean centennial parallactic motions for stars of each magnitude. These calculated parallactic motions are then compared with the mean relative proper motions, as determined from our plates, of stars of these magnitudes. The comparison is contained in Table II.

TABLE II.

Mag.	No. of Stars.	μ_x Meas.	p_x Calc.	Diff.	μ_y Meas.	p_y Calc.	Diff.
7 – 8	3	+0".3	+1".2	+0".9	−1".3	−1".3	0".0
8 – 9	14	+0".2	+1".0	+0".8	−0".6	−1".1	−0".5
8·5 – 9·5	28	−0".1	+0".8	+0".9	−0".2	−0".9	−0".7
9 – 10	20	−0".1	+0".6	+0".7	−0".1	−0".7	−0".6
Adopted				+0".9			−0".7

It will be noticed that the quantity in the column headed "Diff.," *i.e.* $\mu_x - p_x$ where p_x is the mean parallactic motion, is practically constant. The correction thus obtained, when applied to the relative proper motions, gives the absolute proper motions tabulated in Table I. under μ_x and μ_y.

6. *The Motion of the Cluster M36 (N.G.C. 1960).*—All the stars which appear to share the cluster motion are marked with a C in Table I. It will be seen that they are 47 in number. This should be compared with the estimate of Scheiner and Graff, who state that the cluster contains 50 stars. About 15 stars which fall within the cluster on the plate do not appear to share its motion.

The mean proper motion of the cluster, derived from the 47 marked stars, is

$$\mu_x = +0''.5 \text{ per century}$$
$$\mu_y = -0''.9 \text{ per } ,,$$

The parallax of M36 is given by Raab† as 0".0013.

7. *Systematic Motions of the non-cluster Stars.*—The systematic motions were studied by means of a scatter diagram, and the drift curve was constructed in the usual way. Evidence of star-streaming was looked for in the drift curve. A distinct drift was shown in the direction appropriate to Stream I. Stream II. could scarcely be expected to give a perceptible effect, as the plate centre lies near its antapex. No effect attributable to Stream II. was found. In addition to the drift due to Stream I., there appears to be a local drift in the positive direction along the x axis. This does not seem to be traceable to any known cause.

I should like to thank Professor Eddington for permission to use the Sheepshanks Equatorial of the Cambridge Observatory, and Mr. W. M. Smart for help in the course of the investigation.

* *Groningen Publications*, No. 8, p. 24.

† *Lund Meddelanden*, No. 28, "A Research on Open Clusters," Sigfrid Raab, 1922.

The Systematic Motions of Stars of Type A deduced from their Radial Velocities. By G. Shajn.

(*Communicated by the Astronomer Royal.*)

The following investigation of the systematic motions of stars of type A is based on Voûte's "First Catalogue of Radial Velocities." The number of stars of type A there given is 358, whilst in the paper of Eddington and Hartley (*M.N.*, 75, 521–530) the number of stars of the same type is only 212. I have previously computed the elements of sun's motion in the usual way from 362 * stars (60 groups), with the result

$$\text{R.A.} = 263^\circ. \qquad \text{Decl.} = +25^\circ. \qquad V = -15{\cdot}3. \qquad K = +0{\cdot}5.$$

For the investigation of systematic motion the whole sky was divided into 48 regions of equal area (Charlier). The regions c_1 to c_{12} and d_1 to d_{12} are situated along the galactic equator between latitudes $0 \pm 30^\circ$; b_1 to b_{10} and e_1 to e_{10} are situated between latitudes $\pm 31^\circ \pm 66^\circ$, and a_1, a_2, f_1, f_2 in latitudes higher than $\pm 67^\circ$.

The average velocity corrected for the sun's motion † was computed for each area (the correction for the sun's motion and K-term was determined separately for each star). I followed the method of the general integral function of the direction-cosines employed by Strömberg ‡ and Hough-Halm, and at first limited myself to terms of even degrees, joining opposite regions of the sky in pairs. The material was investigated in three separate combinations: (1) all stars of type A (362); (2) only the later stars of this type A1–A9 (203); (3) only the earliest stars A0 (159, including A_p). Some stars with a radial velocity higher than 40 km. per sec. were omitted as well as stars with common movement. The stars of the Taurus cluster are peculiarly dangerous, because their radiant is very near to the vertex, and by their great velocities they may considerably increase the phenomenon of star-streaming.

For these groups I found the following equations representing the radial velocities:—

Gp. I. $V = 10{\cdot}47 + 1{\cdot}39\cos^2 b\cos 2l - 1{\cdot}08\cos^2 b\sin 2l - 1{\cdot}84(2-3\cos^2 b) - 1{\cdot}02\sin 2b\cos l + 1{\cdot}20\sin 2b\sin l.$

Gp. II. $V = 10{\cdot}75 + 2{\cdot}85\cos^2 b\cos 2l - 2{\cdot}02\cos^2 b\sin 2l - 2{\cdot}35(2-3\cos^2 b) - 1{\cdot}30\sin 2b\sin l + 0{\cdot}14\sin 2b\cos l.$

Gp. III. $V = 10{\cdot}04 - 1{\cdot}87\cos^2 b\cos 2l - 2{\cdot}04\cos^2 b\sin 2l - 2{\cdot}32(2-3\cos^2 b) - 1{\cdot}35\sin 2b\sin l + 1{\cdot}83\sin 2b\cos l$

The values of the coefficients and their mean error were found from a least-squares solution. The majority are evidently real.

10·47	±0·35	10·75	±0·48	10·04	±0·69
+ 1·39	·67	+ 2·85	·91	− 1·87	1·37
− 1·08	·67	− 2·02	·91	− 2·04	1·26
− 1·84	·39	− 2·35	·57	− 2·32	0·78
− 1·02	·69	− 1·30	·99	− 1·35	1·38
+ 1·20	·66	+ 0·14	·90	+ 1·83	1·27

* With a few additions to Voûte's Catalogue.
† Assumed Apex $270^\circ + 30^\circ$, $V = -17{\cdot}7$.
‡ *Ap. J.*, 47, 1, 1918.

In order to find if there are systematic differences in the average radial velocities in opposite regions, I have computed for Group I. only the terms of the first and third orders. One half of these differences of the average radial velocities represent the effect, and the expression for the asymmetrical terms is the following :—

$$\frac{\Delta V}{2} = -0\cdot07\cos b\cos l + 0\cdot47\cos b\cos l - 1\cdot04\sin b + 0\cdot44\cos^3 b\cos 3l + 0\cdot41\cos^2 b\sin l$$
$$- 0\cdot86\cos 3b\cos l - 0\cdot18\cos 3b\sin l - 0\cdot13\sin 3b - 0\cdot64\cos^2 b\sin b\cos 2l$$
$$- 1\cdot73\cos^2 b\sin b\sin 2l.$$

The mean errors of the coefficients are respectively $\pm 0\cdot69$, $0\cdot69$, $0\cdot75$, $0\cdot81$, $0\cdot81$, $0\cdot81$, $0\cdot78$, $0\cdot57$, $0\cdot72$, and $0\cdot81$.

The terms are almost all not real. But we have some indications of an asymmetry of the velocity surface.

In order to find how the velocity surface I. (adding two asymmetrical terms) represents the observations, I computed the theoretical values of average radial velocities for each area (Table I.).

TABLE I.

Region.	No.	V. obs. km.	V. comp. km.	C−O. km.	Region.	No.	V. obs. km.	V. comp. km.	C−O. km.
a_1	13	7·6	5·9	−1·7	f_1	...	...	...	...
a_2	5	7·4	5·5	−1·9	f_2	4	14·0	10·3	−3·7
b_1	11	7·8	7·6	−0·2	e_1	4	16·1	12·1	−4·0
b_2	13	7·5	7·0	−0·5	e_2	5	8·8	10·7	+1·9
b_3	11	6·2	9·3	+3·1	e_3	6	6·8	8·3	+1·5
b_4	14	10·7	12·4	+1·7	e_4	10	6·0	7·5	+1·5
b_5	13	11·8	12·2	+0·4	e_5	8	10·4	9·0	−1·4
b_6	10	11·0	8·8	−2·2	e_6	5	8·8	10·7	+1·9
b_7	4	6·0	6·2	+0·2	e_7	2	11·9	11·5	−0·4
b_8	3	4·1	6·9	+2·8	e_8	6	8·3	10·7	+2·4
b_9	6	9·5	9·2	−0·3	e_9	4	9·5	10·7	+1·2
b_{10}	12	9·2	9·4	+0·2	e_{10}	12	12·6	11·7	−0·9
c_1	14	10·1	11·4	+1·3	d_1	10	12·8	13·7	+0·9
c_2	9	12·9	9·3	−3·6	d_2	12	8·4	12·2	+3·8
c_3	5	10·9	9·8	−1·1	d_3	11	12·1	10·5	−1·6
c_4	5	14·1	12·2	−1·9	d_4	10	11·0	10·3	−0·7
c_5	12	14·7	14·5	−0·2	d_5	13	12·4	11·4	−1·0
c_6	12	15·7	17·6	−1·1	d_6	8	13·5	12·7	−0·8
c_7	3	9·4	12·0	+2·6	d_7	6	17·4	13·1	−4·3
c_8	3	7·2	9·3	+2·1	d_8	6	10·6	12·2	+1·6
c_9	5	11·6	8·8	−2·8	d_9	6	13·8	11·5	−2·3
c_{10}	6	9·4	10·8	+1·4	d_{10}	4	11·7	11·7	0·0
c_{11}	...	...	...	...	d_{11}	...	...	...	...
c_{12}	7	14·0	13·2	−0·8	d_{12}	4	15·9	14·1	−1·8

The agreement is good enough, in view of the small number of stars. For the regions f_1, c_{11}, and d_{11} the number of stars is less than 4, and they were omitted.

The principal axes of the velocity surface were found by the use of the discriminating cubic in the usual way.

Results.—The small value of the velocity of solar motion $V = -15{\cdot}3$ confirms the result obtained by Campbell, * and this alone shows that the stars of type A have a systematic motion. The velocity surface, which represents well enough the observations, manifests sufficiently precisely three principal directions (Table II.). There is a close agreement between the direction of the greatest axis and the usually adopted position of the vertex. The greatest and the mean axis lie in the plane of Milky Way, and the least axis is therefore directed towards its pole. Evidently the Milky Way is a fundamental plane for the movements of stars of type A (Table I.).

TABLE II.

Type.	Greatest Axis.			Mean Axis.			Least Axis.			No.
	α.	δ.	V.	α.	δ.	V.	α.	δ.	V.	
A	100°·0	+23°·0	14·4	312°·1	+63°·2	10·5	192°·5	+17°·0	6·3	362
A1–A9	98·6	+18·5	16·2	340·6	+55·1	9·6	200·5	+29·0	5·9	203
A0	72·7	+62·3	15·6	298·1	+20·4	10·8	198·4	+21·0	4·9	159

The small value of the terms of 1 and 3 order shows that as a first approximation the velocity surface is an ellipsoidal one, with, however, some indication of asymmetry. The two axes of the maximum radial velocities do not form a straight line, but the material is evidently insufficient to indicate a real deviation from 180°.

A sub-division of the stars of type A shows that the star-streaming is developed fully in the later Group A. The earliest stars A0 also show strong systematic motions. This in general confirms the results obtained by Eddington and Hartley, though the direction of the greatest axis is now a little nearer to the usually adopted position of the vertex. The greatest and mean axes of the velocity surface A0 are turned in the plane of the Milky Way approximately 47° forward relatively to A1–A9.

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1922 *December.*

* *L.O. Bulletin*, 211.

The Disturbing Action of the Earth on Meteoric Showers.

By G. Shajn.

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In the present paper the disturbing action of the earth on meteoric showers is discussed. The complexities of the phenomena of meteoric showers have to be considered partly as a consequence of this action. This question has not hitherto been investigated in detail.*

At an encounter of the earth with a meteoric shower some of the meteors fall on the earth, while others, more distant, will go aside, although they will undergo considerable perturbations. I do not examine here the question of the zenith-attraction.

The selection of the earth as a general factor of disturbing action was made for the following reason. Our knowledge of the meteoric showers is limited only to those which cross the earth's orbit and produce a radiant. The probability that they also cross the sphere of action of the great planets is small. In individual cases the disturbing action of the great planets is considerable, but the pre-eminent rôle for the majority of the known meteoric showers belongs to the earth. At succeeding encounters with the earth the already once perturbed meteors will fall, the radiant of which will differ from that of the undisturbed ones, which encounter the earth for the first time. The elements of the meteoric orbits of different parts of the same shower will be somewhat different.

The theory of the capture of the comets (Tisserand, Callandreau, and H. A. Newton) can be applied to the meteors. But I have preferred to compute the perturbations by the method of special perturbations "Variation of Constants," according to Oppolzer's "Bahnbestimmung II." It was possible to make some simplifications, as the passing of the meteors occurs near the nodes and Δ is a quantity of considerably smaller order than i or i'. After some trials it appeared that for the preciseness of the computations the unit of time w must be taken between 1–15 minutes.

The perturbations depend in considerable degree on the conditions of the passage of the meteors through the sphere of action of the earth. For that reason I selected two characteristic showers, Perseids and Andromedids, the elongations of which from the apex are respectively 67° and 158°. For each shower I selected two meteors: (1) the meteor crosses the earth's orbit, when the earth has not yet reached the intersecting point of their orbits ("meteor passing ahead of the earth"); (2) if the earth has already passed the intersecting point, this case is called "meteor passing behind earth."

The perturbations were computed for a particular case (distance of the meteor from the earth at the moment of intersection with the earth's

* See the investigations of Schiaparelli, Niessl, H. A. Newton, Bredichin, Turner, Adams, Twining, Moulton, Gylden, Jeffreys, Tessenkoff, and others. With the investigations of the two last authors I only became acquainted after this paper was already written in the rough.

orbit about 0·00013). For that reason our computations have a qualitative rather than a quantitative character, and deviations are possible to either side though the general character remains invariable. The values of perturbations for each shower are as follows:—

	Andromedids.		Perseids.	
	Meteor passing ahead of the Earth.	Meteor passing behind the Earth.	Meteor passing ahead of the Earth.	Meteor passing behind the Earth.
$\Delta\Omega$	$-25''\cdot3$	$-25''\cdot4$	$-0''\cdot3$	$-0''\cdot4$
Δi	$+1^\circ\,35'\cdot6$	$-1^\circ\,27'\cdot5$	$+1^\circ\,6'\cdot5$	$-34'\cdot0$
$\Delta\pi$	$+5^\circ\,48\cdot4$	$-5^\circ\,26'\cdot3$	$-27'\cdot6$	$+22'\cdot6$
$\Delta\phi$	$-10^\circ\,1'\cdot9$	$+9^\circ\,20'\cdot8$	$-4^\circ\,9'\cdot0$	...*
$\Delta\mu$	$+433''\cdot2$	$-322''\cdot7$	$+20''\cdot2$	...
Δa	$-1\cdot162$	$+3\cdot087$	$-7\cdot260$	...

The perturbations of the semi-axis were examined in some detail, taking as starting-point the investigations of H. A. Newton, Tisserand, and Callandreau. I give here the results for the aforesaid showers:—

Nearest Distance of the Meteor from the Earth. km.	Andromedids (Initial Semi-axis = 3·544).		Perseids (Initial Semi-axis = 24·534).	
	Disturbed Semi-axis by passing ahead of the Earth.	Disturbed Semi-axis by passing behind the Earth.	Disturbed Semi-axis by passing ahead of the Earth.	Disturbed Semi-axis by passing behind the Earth.
500	1·107	hyperbola	+ 7·735	hyperbola
1000	1·166	,,	+ 7·790	,,
1500	1·223	,,	+ 8·421	,,
2000	1·278	,,	+ 8·966	,,
3000	1·382	,,	+ 9·972	,,
4000	1·478	+68·027	+11·148	,,

It is necessary to note that, according to a criterion of Clausen, the disturbed orbits have a common intersecting point with the undisturbed initial orbit, and this point will lie close to the point occupied by the disturbing planet.

Now I shall indicate some consequences, which follow from the preceding.

The parallelism of the orbits of individual meteors in the shower must be broken after several crossings of the shower with the earth. The perturbations of different signs will mutually cancel and others of the same sign will be increased. The result of this effect will appear as an area of radiation. According to the perturbations obtained, I have computed the variation in the position of the radiant in longitude and latitude.

* If the orbit is near to a parabola the formulæ of the method of "Variations of Constants" are inapplicable.

	Andromedids.		Perseids.	
	I. Case.	II. Case.	I. Case.	II. Case.
Δl	$+3^\circ 31'$	$-12^\circ 30'$	$-1^\circ 0'$	...
Δb	$+4^\circ 34'$	$-2^\circ 40'$	$+0^\circ 12'$	...

For a shower with a large elongation, a few revolutions is sufficient for the formation of a considerable area of radiation. The dispersion of the area of radiation increases with the elongation from the apex and with the age of the shower.

Observation confirms this theoretical deduction. The Perseids are evidently very old, and at moderate elongation they must give naturally a large dispersion of radiation. It is known that Geminids and Aquarids of July give a large dispersion of radiation, and their elongations are large (100° and 106°). Among the showers with a well-defined small radiant area we have to note the Orionids and Lyrids (whose elongations are respectively 16° and 40°). The Andromedids at their second apparition in 1855 had a small area of radiation (8°–10°), but now the dispersion of radiation is very large.

The variation in longitude is generally larger than in latitude, particularly for showers with a great elongation. In this case we shall have a definite form for the area of radiation, with the larger extension in longitude. Observation in general confirms this result (Andromedids, Aquarids of July, Geminids, and others).

Showers with a small elongation will be stable for a long time. On the contrary, a shower with large elongation will be soon dispersed, and we shall obtain individual radiants and even sporadic meteors. Rich showers with a large elongation cannot therefore exist for a long time. Of the known rich showers only the Andromedids have a large elongation (158°); and they have now ceased to appear as a rich shower. All the remaining rich showers have moderate elongations (maximum 110°). It seems impossible to consider such distribution of large showers as simply fortuitous. In the vicinity of the antiapex only feeble dispersed radiants can exist, and this is well established by observation.

For that reason we do not know the showers corresponding to comets of short period (excluding Andromedids and the meteors of comet Pons-Winnecke). The traces of their dispersed radiation must be scattered in the vicinity of the antiapex. It is desirable that particular attention should be paid to this region of the sky by meteor observation.

From the above table it will be seen that the perturbations of the semi-axis are large. The meteors of the initial cluster will be spread out along the orbit. This argument completes and generalises the reasonings of Schiaparelli on the spreading of an initial cluster as a consequence of unequal action of the sun's attraction upon its different parts. The older a shower is, the greater will the number of perturbed meteors become, and the maximum will be less and less prominent. In this case the elongation seems also to play a definite rôle.

It follows from the above table that in a shower with a large elongation perturbed orbits of a very short period of revolution are formed. In this case an encounter with the earth is possible in both nodes. The

condition $\pi - \Omega = 90^\circ$ is here not indispensable. For a considerable number of radiants of the northern sky a second dispersed radiant must be observed in the southern sky after six months, and conversely. For example, the Andromedids must give in southern hemisphere a radiation ($\alpha = 255^\circ \pm 10^\circ$; $\delta = -48^\circ \pm 10^\circ$) at about the end of May. Radiants of southern hemisphere are not sufficiently well known, but catalogues indicate about this epoch and near this region some similar radiants. The *polarity* of certain showers must exist indubitably, and will be proved as soon as the southern sky is investigated sufficiently.

Taking account of this effect, we are not surprised that the number of radiants considerably surpasses the number of comets. Many of the radiants in the catalogues are not independent.

The tables show that an elliptic orbit can be transformed into a hyperbolic one, and therefore the disturbing action is one of the causes of a gradual scattering of the showers. On the other hand, ellipses of very short period of revolution can be formed. Taking account of this effect, we can imagine the possibility of a radiation of the same showers through a few months in the same region of sky (near to the ecliptic), *i.e.* a phenomenon similar to stationary radiants.

The theory of the capture of comets has here a wide application. We have some reason to think that meteoric showers can exist independently of comets. An immense number of the meteoric orbits are daily transformed into short-period ellipses. For that reason the secular action of all planets is such that we will get a secular accumulation of the meteors, and their density will increase with the approximation to the sun.

Summary.

(1) Many details of the complicated phenomenon of meteoric showers must be considered mainly as a consequence of the disturbing action of the earth.

(2) The perturbations depend in considerable degree on the conditions of the passage of the meteors through the sphere of action of the earth; the values of these perturbations have been obtained by the method of "Variation of Constants" for four particular cases.

(3) The general consequences are: (*a*) a formation of an area of radiation; (*b*) a peculiar form of this area; (*c*) the stability of the showers and the peculiar distribution of the rich showers; (*d*) the feeble and dispersed radiation in the vicinity of antiapex; (*e*) the spreading of the meteors along the orbit; (*f*) the polarity of the radiation; (*g*) the abundance of the meteoric showers and the number of comets; (*h*) an increase of the density of the meteors with approach to the sun as a consequence of the secular disturbing action of the planets.

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Mean Areas and Heliographic Latitudes of Sunspots in the Year 1920.

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The results here given are in continuation of those in the *Monthly Notices*, 83, 94, and are derived from the measurement of photographs taken at the Royal Observatories of Greenwich and the Cape, and in India at Kodaikánal Observatory and at Dehra Dûn.

Table I. gives the mean daily area of umbræ, whole spots, and faculæ for each synodic rotation of the Sun for the year 1920, and Table II. gives the same particulars for each entire year from 1913 to 1920 inclusive. The areas are given in two forms: firstly, projected areas, *i.e.* as seen and measured on the photographs, these being expressed in millionths of the Sun's apparent disc; secondly, areas corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere.

Table III. gives for each rotation in the year 1920 the mean daily area of the whole spots (corrected for foreshortening), and the mean heliographic latitude of the spotted areas for spots north and for spots south of the equator, together with the mean heliographic latitude of the entire spotted area and the mean distance from the equator of all spots. Table IV. gives the same information for each year as a whole from 1913 to 1920. Tables II. and IV. are thus in continuation of similar tables for the years 1874 to 1888 on pp. 381 and 382 of vol. xlix. of the *Monthly Notices*; for the years 1889 to 1902 on pp. 465 and 466 of vol. lxiii., and for the years 1901 to 1914 on pp. 402 and 403 of vol. lxxvi.

The rotations in Tables I. and III. are numbered in continuation of Carrington's series (*Observations of Solar Spots made at Redhill*, by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853 November 9. The assumed prime meridian is that which passed through the ascending node at mean noon of 1854 January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days.

The principal features of the record for the year 1920 are as follows:—

1. The pronounced decline in the mean daily area of spots from 1052 (corrected for foreshortening) for the year 1919 to 618 for the year 1920.

2. Two rotations stand out prominently for their activity, *i.e.* Rotations 887 and 889, which contained two remarkably large "streams." Rotation 891 with a mean daily area of 227 is the least active since Rotation 820 (1915 January).

3. The mean daily area of faculæ shows a decrease of 30 per cent. as compared with the previous year. The fluctuations in activity during the year are much less than for the spots.

4. Comparing the two hemispheres, the greater activity is markedly in the southern (34 per cent. in the northern and 66 per cent. in the southern). This marked difference is due largely to the three very extensive spot groups of January, March and September, with mean daily areas of 1500, 2000, and 1100 millionths respectively. This is

the first year during the present cycle that the spot activity in the southern hemisphere has preponderated.

5. The mean latitude of 10°·4 is nearly the same as for the spots of the previous year. This distribution in latitude corresponds in earlier cycles to that shown about four years after the maximum.

6. The distribution in longitude of the spot groups for the year shows a specially active region, about 40° in extent in longitude with centre about 125°, and two relatively quiescent regions with centres about longitudes 70° and 260° respectively, the former being particularly well marked.

7. On four days during the year, no spots were visible on the Sun's disc. These are the first occasions since the year 1916.

8. The number of separate groups lasting for at least two days was 187, as compared with 305 for the year 1919. Of the 187 groups, 92 were in the northern and 95 in the southern hemisphere. Besides these, there were recorded 123 small groups (mostly consisting of one or of two very small spots) visible for one day only; 58 were in the northern and 65 in the southern hemisphere.

TABLE I.

No. of Rotation.	Rotation Commenced G.M.T. (Civil).		No. of Days on which Sun photographed.	Mean of Daily Areas.					
				Projected.			Corrected for Foreshortening.		
				Umbræ.	Whole Spots.	Faculæ.	Umbræ.	Whole Spots.	Faculæ.
	1920	d							
887	Jan.	9·86	27	278	1686	1253	192	1166	1434
888	Feb.	6·20	28	151	806	1341	100	542	1544
889	Mar.	4·54	27	384	2156	1444	272	1575	1703
890	Mar.	31·84	27	84	429	966	67	348	1068
891	Apr.	28·11	27	56	280	968	43	227	1119
892	May	25·33	28	134	692	1080	94	498	1199
893	June	21·53	27	146	699	985	105	537	1154
894	July	18·73	27	56	301	879	44	242	998
895	Aug.	14·95	27	126	736	628	97	575	724
896	Sept.	11·20	27	160	824	934	128	684	1137
897	Oct.	8·48	28	193	942	1224	132	656	1392
898	Nov.	4·78	27	127	688	1097	96	518	1322
899	Dec.	2·09	28	114	587	971	82	427	1129

TABLE II.

Year.	No. of Days on which Sun photographed.	Projected.			Corrected for Foreshortening.		
		Umbræ.	Whole Spots.	Faculæ.	Umbræ.	Whole Spots.	Faculæ.
1913	365	2	10	87	1	7	95
1914	365	40	195	396	31	152	454
1915	365	186	920	1289	137	697	1521
1916	365	186	978	1512	135	724	1785
1917	365	346	2101	1882	247	1537	2305
1918	364	255	1504	1526	188	1118	1882
1919	365	253	1437	1445	182	1052	1729
1920	366	156	837	1052	112	618	1219

TABLE III.

No. of Rotation.	Rotation Commenced G.M.T. (Civil).		Spots NORTH of the Equator.		Spots SOUTH of the Equator.		Mean Heliographic Latitude of entire Spotted Area.	Mean Distance from Equator of all Spots.
			Mean of Daily Areas.	Mean Heliographic Latitude.	Mean of Daily Areas.	Mean Heliographic Latitude.		
	1920	d		°		°	°	°
887	Jan.	9·86	166	5·63	1001	9·81	− 7·61	9·21
888	Feb.	6·20	277	8·74	265	12·54	− 1·66	10·60
889	Mar.	4·54	371	10·21	1204	5·91	− 2·11	6·92
890	Mar.	31·84	51	9·07	297	6·34	− 4·06	6·75
891	Apr.	28·11	135	12·22	92	7·03	+ 4·43	10·12
892	May	25·33	425	12·58	72	8·94	+ 9·46	12·05
893	June	21·53	302	13·94	236	14·11	+ 1·63	14·01
894	July	18·73	140	12·39	103	15·99	+ 0·35	13·92
895	Aug.	14·95	32	12·04	543	14·84	−13·35	14·69
896	Sept.	11·20	284	10·66	400	11·75	− 2·46	11·30
897	Oct.	8·48	227	12·12	429	12·84	− 4·20	12·59
898	Nov.	4·78	104	14·74	414	9·80	− 4·88	10·79
899	Dec.	2·09	222	12·14	205	10·77	+ 1·16	11·48

TABLE IV.

Year.	No. of Days on which Sun photographed.	Spots NORTH of the Equator.		Spots SOUTH of the Equator.		Mean Heliographic Latitude of entire Spotted Area.	Mean Distance from Equator of all Spots.
		Mean of Daily Areas.	Mean Heliographic Latitude.	Mean of Daily Areas.	Mean Heliographic Latitude.		
			°		°	°	°
1913	365	5	24·81	2½	20·08	+9·81	23·23
1914	365	99	21·11	53	23·06	+5·71	21·79
1915	365	379	17·95	318	19·75	+0·77	18·77
1916	365	470	15·14	254	17·05	+3·83	15·81
1917	365	860	13·82	677	15·66	+0·84	14·63
1918	364	609	11·97	509	13·69	+0·29	12·75
1919	365	559	9·85	493	11·79	−0·28	10·76
1920	366	208	11·31	410	9·98	−2·83	10·43

Royal Observatory, Greenwich:
1923 *February* 27.

Addendum to Note on the Motion of the Magellanic Clouds.

By Ejnar Hertzsprung.

Since the above note * was printed, I found in the First Catalogue of Radial Velocities, edited by J. Voûte (*Natuurkundig Tydschrift voor Ned.-Indie*, 80, 97), the following two nebulæ—one belonging to the lesser and one to the greater Magellanic Cloud—which are not among the 18 nebulæ contained in *Lick Publ.*, 13 :

α (1900).		δ (1900).		Radial vel.	
h	m	°	′		
1	5·3	−73	25	158	km/s
5	52·6	−69	33	268	

Applying analysis to all 20 nebulæ together, I find with the designations used in the former note :

$$V = -60{\cdot}6 \sin\delta + 209{\cdot}5 \cos\delta \cos\alpha + 580{\cdot}3 \cos\delta \sin\alpha$$

and the mean error :

$$\pm 12{\cdot}0 \text{ km/s } (4{\cdot}4\, x^2 + 33{\cdot}0\, y^2 + 21{\cdot}5\, z^2 + 21{\cdot}5\, xy + 19{\cdot}1\, xz + 44{\cdot}4\, yz)^{\frac{1}{2}}$$

The residuals O − C in order of AR become : −4, +7 ; +19, +13, −7, −14, −18, −4, −9, +16, +9, −18, +13, +6, −5, −7, −13, +1, +8, and +6 km/s.

The motion relative to the sun is 620 km/s ±70 km/s (*m.e.*) towards $4^h\ 41^m \pm 19^m$, $-5^\circ{\cdot}6 \pm 3^\circ{\cdot}0$.

Regarding the angular proper motion of the Clouds, the most promising way of its determination seems to be the photographic connection between stars belonging to the Clouds and stars of the foreground. The difficulty of distinguishing between these two kinds of objects may perhaps to some extent be overcome by making use of the radial velocities, which are so great for stars belonging to the Clouds, that the objective-prism method, proposed by Edw. C. Pickering, may prove to be sufficient to separate them from the stars of the foreground. Of course, the stars in question are very faint, but the differences in radial velocity to be recognised are very great, so that an unusually small dispersion will be sufficient for the purpose.

The secular motion of the fainter stars of the foreground is known accurately enough to be taken into due account by the interpretation of the relative motion finally found between these stars and those belonging to the Clouds.

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* *M.N.R.A.S.*, 80, 782, 1920.